§5. Simulation Study of High-energetic Particle Confinement in the D-shaped Helical Fusion Reactor

Watanabe, T.

To realize fusion reactors at an early stage, it is necessary to mitigate the severe engineering issues, by innovative concept of core plasma physics. We have proposed a geodesic winding helical reactor with D-shaped magnetic surface [1]. The geodesic winding D-shaped helical magnetic field configuration has the following merits. ① The geodesic winding allows the tightening winding of the helical coils. ② The stability of high-beta and high-density plasma because of the magnetic well in the core plasma region and the high magnetic shear in the peripheral region. ③ The improvement in confinement because of the large plasma volume and D-shaped magnetic surface.

Using the trapped particle orbit diagram (TPOD) [2], it is shown that the loss-cone depth becomes shallow when the magnetic axis is shifted to the inner side. On the other hand, the loss-cone depth can reach to the magnetic axis when the magnetic axis is shifted fairly to the outer side. The geodesic winding D-shaped helical magnetic field configuration can actively control the confinement and exhaust of alpha particles (Fig. 1).

Active control of the confinement and exhaust of 3.52 MeV alpha particles by controlling the magnetic axis position is confirmed by collisionless orbit calculations (Fig. 2).

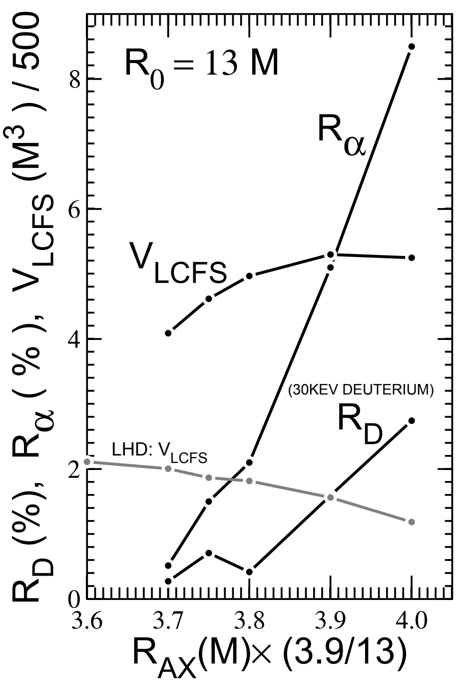

Fig. 1: The dependence of the magnetic axis position R_{ax} to the direct loss rate of 3.52 MeV alpha particle (R_α) and of fuel ions (R_{D} for 30 keV deuterium), in the geodesic winding D-shaped helical magnetic field configuration. The magnetic axis positional dependence of the volume of the LCFS V_{lcfs}, in the case of a geodesic winding fusion reactor and of the LHD winding fusion reactor are also shown. The major radius of helical coils is assumed to be $R_0 = 13\,\mathrm{m}$. $B_{\mathrm{ax}} = 7\,\mathrm{T}$. The elongation factor of the winding frame of the helical coils is set to be $\kappa = 1.83$.

1) T.Watanabe, Reduced-Size LHD-Type Fusion Reactor with D-Shaped Magnetic Surface , (PFR. 7, 2403113-1-5 (2012)).

2) Tsuguhiro WATANABE, Alpha-Particle Confinement Control of the Geodesic Winding of LHD-Type Fusion Reactors, (PFR, 8, 2403072 (2013)).

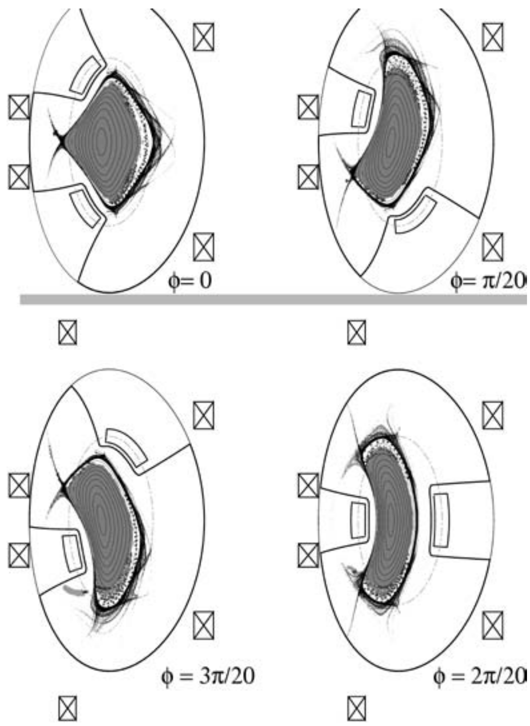

Fig. 2: The numerical computations of the collisionless orbit of 3.52 MeV alpha particles. The birth position of alpha particles is uniform inside the magnetic surface of $\rho/\rho_{\mathrm{lcfs}} \leq 0.8$. The initial pitch angle is also uniform in the range $[0, \pi]$. The position of the magnetic axis is $3.75 \times 13/3.9$m (inner shift case).